PNEUMATIC TOOL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional patent application Serial No's. 60/430,611, filed December 3, 2002; 60/430,550, filed December 3, 2002; and 60/430,610, filed December 3, 2002, all of which are herein incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention generally relates to a pneumatic tool having an impactor device, e.g., piston and tool bit, for impacting a workpiece. More specifically, the present invention relates the pneumatic tool having an energy absorbing mechanism for absorbing kinetic energy of the impactor device during use to prevent the destruction of components of the pneumatic tool, such as during a dry fire, while otherwise providing a high impacting force to the workpiece.

BACKGROUND OF THE INVENTION

[0003] Pneumatic tools offer a "best-fit" solution in many applications because of their safety, reliability, and simplicity. Typically, however, pneumatic tools for impacting a workpiece by delivering hammering blows, e.g., pneumatic hammers, have characteristics that detract from their utility or preclude their use in some applications such as breaking off casting risers on a production line, or seating large press-fit assemblies.

[0004] A pneumatic tool for impacting a workpiece by delivering hammering blows, whether percussive or single stroke, is normally designed to produce an impact via a slidable impactor device. Typically, the impactor device comprises a tool bit that is held against a workpiece before impact and a piston for impacting the tool bit and transferring kinetic energy through the tool bit to the workpiece to perform the necessary work. The travel of the tool bit is fairly short and constrained by the workpiece. The kinetic energies developed in the impactor device are primarily absorbed by the workpiece. Any residual kinetic energies are usually small and dissipated in tool components with the help of springs or elastic pads, if necessary, to moderate the resulting forces. However, some applications, such as breaking off casting risers on a production line, require the impactor device to carry high kinetic energy throughout a relatively long stroke to impact

workpieces at varying distances. Residual kinetic energies, and the forces from their dissipation, can be quite high. In these types of applications, an energy absorbing mechanism is necessary to dissipate high kinetic energies from the impactor device without the subsequent destruction of other tool components, especially in the event of a dry fire, in which the pneumatic tool is actuated with the tool bit being improperly positioned relative to the workpiece. In such an event, without an energy absorbing mechanism, tool components can be subjected to large destructive forces.

[0005] One example of such an energy absorbing mechanism in a pneumatic tool is shown in United States Patent No. 6,364,032 issued to DeCord, Jr. et al. DeCord, Jr. et al. discloses a pneumatic tool having an elongated casing defining a chamber. An impactor device is slidable within the chamber along an operational axis. A valve system slides the impactor device within the chamber by selectively introducing and releasing pressurized fluid into and out from the chamber. An energy absorbing mechanism is slidably supported within the chamber for dissipating the kinetic energy of the impactor device. The energy absorbing mechanism comprises a nylon disc and a pressure chamber between the nylon disc and a distal end of the elongated casing. A pressurization valve pressurizes the pressure chamber. The nylon disc slides against pressurized fluid in the pressure chamber upon impact by the impactor device to dissipate kinetic energy of the impactor device. The nylon disc is continuously subjected to hammering impacts from the impactor device without any prior or subsequent dissipation of kinetic energy by the energy absorbing mechanism. Thus, in the event of a dry fire, any kinetic energy in the impactor device must either be absorbed by the nylon disc and the pressurized fluid in the pressure chamber, or by other components of the tool.

BRIEF SUMMARY OF THE INVENTION AND ADVANTAGES

[0006] The present invention provides a tool for impacting a workpiece. The tool comprises a casing having a proximal end and a distal end with a chamber defined therebetween. An impactor device is slidable within the chamber along an operational axis. A valve system slides the impactor device within the chamber by selectively introducing and releasing fluid pressure into and out from the chamber. An energy absorbing mechanism reduces kinetic energy of the impactor device as the impactor device slides within the chamber. The energy absorbing mechanism comprises a sleeve that slides along the casing and first and second pressure chambers to reduce the kinetic energy of the

impactor device. The first pressure chamber is defined between the impactor device and the sleeve and the second pressure chamber is defined between the casing and the sleeve. The first pressure chamber reduces the energy of the impactor device in a first stage immediately after movement thereof by compressing pressurized fluid within the first pressure chamber. The second pressure chamber reduces the energy of the impactor device in a second stage after compression in the first pressure chamber and when the impactor device impacts the sleeve.

[0007] The present invention yields several advantages over the prior art. For instance, two pressure chambers are provided to reduce the kinetic energy of the impactor device as the impactor device slides in the casing. As a result, energy dissipation occurs in at least two stages. In the first stage, the energy of the impactor device is dissipated primarily by compressing pressurized fluid in the first pressure chamber between the impactor device and the sleeve. In the second stage, after the impactor device impacts the sleeve, the energy of the impactor device is dissipated primarily by compressing pressurized fluid in the second pressure chamber. This multi-stage approach to energy dissipation using multiple pressure chambers reduces the potentially destructive hammering forces that may otherwise be experienced in a pneumatic tool such as one that absorbs kinetic energy in a single stage by directly impacting a energy absorbing component of the tool. Furthermore, the multi-stage approach to energy dissipation balances a need for smaller, more maneuverable tools with the need for high kinetic energies. Using two pressure chambers provides a more compact tool design. At the same time, the two pressure chambers prolong the kinetic energy dissipation such that the impactor device can still perform high-energy work.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0008] Advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0009] Figure 1 is a perspective view of a tool of the present invention;

[0010] Figures 2A-2B are schematic illustrations of the tool of the present invention in an un-actuated and an actuated stage, respectively;

[0011] Figure 3 is a perspective view of an exhaust valve of the present invention;

[0012] Figures 4A-4C are cross-sectional views of the exhaust valve illustrating three stages of the exhaust valve;

[0013] Figure 4D is a blown-up view of an air groove in a sliding sleeve of the exhaust valve;

[0014] Figures 5A-5D are cross-sectional views of a pilot valve of the present invention illustrating four stages of the pilot valve;

[0015] Figures 6A-6C are cross-sectional views of a bleeder valve of the present invention illustrating three stages of the bleeder valve;

[0016] Figure 7 is an end elevational view of the tool indicating a location of the bleeder valve;

[0017] Figure 8 is a perspective view of a poppet body of the bleeder valve;

[0018] Figures 9A-9C are partially broken perspective views of an energy absorbing mechanism of the present invention illustrating three stages of the energy absorbing mechanism;

[0019] Figures 10A-10C are cross-sectional views of the energy absorbing mechanism from Figs. 9A-9C illustrating the three stages of the energy absorbing mechanism;

[0020] Figure 10D is a blown-up view of a bleed passage;

[0021] Figures 11-12 are cross-sectional views of the energy absorbing mechanism taken generally along the lines 11-11 and 12-12 respectively of Fig. 10A;

[0022] Figures 13A-13C are cross-sectional views of a shock absorbing valve of the present invention illustrating three stages of the shock absorbing valve;

[0023] Figure 14 is a cross-sectional view of a pressure regulator of the shock absorbing valve;

[0024] Figure 15 is a partially broken perspective view of a pressure reducing check valve of the present invention;

[0025] Figure 16 is a front and rear perspective view of a poppet body of the pressure reducing check valve of Fig. 15;

[0026] Figure 17 is an assembly view of a floating collar, mounting arm, cuff, and handle of the present invention; and

[0027] Figure 18 is a perspective view of an alternative handle of the tool.

DETAILED DESCRIPTION OF THE INVENTION

[0028] Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, a tool for impacting a workpiece **22** is generally shown at **20**. The tool **20** is preferably a pneumatic impacting tool for fracturing a gate or riser from a casting after a foundry pouring process. Of course, the tool **20** may be used for other applications including, but not limited to, breaking concrete or other similar demolition, driving fasteners in construction applications, seating large press-fit assemblies, and the like. The tool **20** is powered by a conventional pressurized fluid source **F**, e.g., an air compressor.

[0029] Referring to FIG. 1, the tool **20** is shown fully assembled and ready for use. A tool bit **24** is shown in a starting position. Upon actuation, the tool bit **24** slides distally to impact the workpiece **22**. An adjuster plate **26** may be used to suspend the tool **20** from a tool balancer **25** to provide added versatility and maneuverability in positioning the tool bit **24** adjacent to the workpiece **22**. The adjuster plate **26** includes a plurality of slots **28** for adjustably receiving a cable **30** of the tool balancer. The slots **28** allow the operator to adjust a balance point and associated weight distribution of the tool **20** for added comfort and maneuverability.

[0030] The tool **20** further comprises a cuff **32** having hook and latch fasteners (not shown) for adjustably and comfortably receiving an arm of an operator. A handle **34** is used to grip and maneuver the tool **20** to position the tool bit **24** in necessary proximity to the workpiece **22**. A hand guard **36** protects a hand of the operator. A trigger **38** is pivotally supported near the handle **34** to actuate the tool **20** and drive the tool bit **24** toward the workpiece **22**. The tool **20** also includes a conventional inlet **40** for receiving a quick connect coupler **41** from the pressurized fluid source **F** to power the tool **20**.

[0031] Referring to FIGS. 2A-2B, the tool **20** and corresponding fluid circuitry are schematically illustrated. FIG. 2A illustrates the tool **20** in an un-actuated position, e.g., prior to pulling the trigger **38**. The tool **20** comprises a casing **42** having a proximal end **44** and a distal end **46**. A chamber **48** is defined within the casing **42** between the ends. The casing **42** comprises a tool barrel **50** for slidably and concentrically sealing and supporting the tool bit **24** and a power barrel **52** for slidably and concentrically sealing and supporting a piston **54**. The tool bit **24** and piston **54** define an impactor device **24, 54** of the tool **20**. The piston **54** slides distally within the power barrel **52** along an operational axis **A** upon actuation to impact the tool bit **24** and drive the tool bit **24** toward the

workpiece **22**. FIG. 2B illustrates the tool **20** in an actuated position, e.g., after pulling the trigger **38**.

[0032] Still referring to FIGS. 2A-2B, an outer casing **56** coaxially and concentrically surrounds the power barrel **52**. A reserve chamber **58** is defined between the outer casing **56** and the power barrel **52**. In the reserve chamber **58**, pressurized fluid is detained to drive the piston **54** distally within the chamber **48**. As will be described further below, the fluid in the chamber **48** distal to the piston **54** is at a first pressure in the un-actuated position, see FIG. 2A, while the fluid in the reserve chamber **58** is at a second pressure less than the first pressure. This pressure differential latches the piston **54** to the proximal end **44** of the casing **42** in the un-actuated position. Upon actuation, the fluid in the chamber **48** distal to the piston **54** is quickly exposed to atmosphere thus thrusting the piston **54** distally to impact the tool bit **24**.

[0033] A valve system **60** controls the actuation of the piston **54** and a piston return cycle, i.e., return of the piston **54** back to the un-actuated position. The valve system **60** comprises a plurality of valves for operating various aspects of the tool **20**. The circuitry of each of the valves is schematically illustrated in FIGS. 2A-2B. It will be appreciated by those skilled in the art, that the manner of carrying out the circuitry illustrated is unlimited. The circuits illustrated could be carried out by simple flexible conduit connections, fluid passages contained in outer casings or cylinders of the tool **20**, or other alternative methods. In FIG. 1, the tool **20** is shown with additional casings and cylinders to carry out the fluid circuitry schematically illustrated in FIGS. 2A-2B.

[0034] A distribution manifold **62** distributes the pressurized fluid from the pressurized fluid source **F** to the valve system **60**, as shown in FIGS. 2A-2B. The fluid routing from the distribution manifold **62** throughout the tool **20** is illustrated using conventional symbols well known to those skilled in the art. Hence, a description of each of the symbols and the specific circuitry for each of the valves will not be further described except with respect to the structure illustrated herein for fluid routing.

[0035] An exhaust valve, schematically represented at **100**, controls the selective introduction and release of pressurized fluid into and out from the chamber **48** distally of the piston **54** to hold the piston **54** in the un-actuated position and to release the piston **54** upon actuation, respectively. The exhaust valve **100** is a tight-sealing, two-position, three-way piloted valve effecting an abrupt, very high flow exhaustion of the chamber **48** of the pressurized fluid upon actuation. In a closed position, the exhaust valve

100 reintroduces pressurized fluid into the chamber **48** to push back and latch the piston **54** to the proximal end **44** against pressurized fluid in the reserve chamber **58**. When actuated, the exhaust valve **100** will cause a very rapid acceleration of the piston **54** to produce a high-energy impact against the tool bit **24**.

[0036] A pilot valve, schematically represented at **200**, controls the exhaust valve **100**. The pilot valve **200** is a tight-sealing, three-way piloted valve designed to produce a sudden actuation of the tool **20** via an abrupt exhaust cycle. The trigger **38** actuates the pilot valve **200** to produce a conventional "on/off" feel, though other means can be used.

[0037] A bleeder valve, schematically represented at **300**, bleeds pressurized fluid from within the chamber **48** proximal of the piston **54** to assist in drawing the piston **54** back to the proximal end **44** in the piston return cycle. The bleeder valve **300** is a tight-sealing, variable flow-rate, sequencing on-off bleeder exhaust valve piloted by the opening of a source of pressurized fluid to be vented. The bleeder valve **300** actuates after a delay and at a cracking pressure, both of which can be adjusted. The bleeder valve **300** can be used to lower the pressure proximally of the piston **54** in the chamber **48** to enable the piston return cycle with minimal air loss and with variable cyclic rate. The bleeder valve **300** responds to a position of the piston **54** in the chamber **48** and requires no connection to any other valve. The bleeder valve **300** enables a length of the casing **42** to be varied with no revision of other valve circuitry.

[0038] A restrictor orifice, schematically represented at **400**, is in fluid communication with the chamber **48** to assist in absorbing energy of the tool bit **24** upon actuation and to return the tool bit **24** to the starting position after actuation. The restrictor orifice **400** is part of an energy absorbing mechanism **402** of the tool **20**, as will be further described below.

[0039] A shock absorbing valve, schematically represented at **500**, reduces shock to the operator caused by the energy being transferred between components of the tool **20** and the workpiece **22** and vice versa. The shock absorbing valve **500** dissipates recoil shock from the tool **20** via compression and release of pressurized fluid. The shock absorbing valve **500** is integrated into the tool **20** to reduce the transmission of potentially bothersome or injurious shock to the operator.

[0040] A pressure reducing check valve, schematically represented at **600**, reduces the pressure of fluid between the distribution manifold **62** and the reserve chamber

58 such that the pressure of the fluid in the reserve chamber **58** is slightly less than that of the pressure of the pressurized fluid source **F**, e.g., one to twenty pounds per square inch less pressure.

[0041] A pressure relief valve is schematically represented at **700** in FIGS. 2A-2B. The pressure relief valve **700** is shown extending from an underside of the tool **20** in FIG. 1 to relieve pressure within the tool **20** when the pressure exceeds a predetermined limit.

[0042] With reference to FIGS. 3 and 4A-4D, the exhaust valve **100** is further described. The exhaust valve **100** comprises a valve housing **102** concentrically fixed to the power barrel **52**. The valve housing **102** acts as a manifold to distribute pressurized fluid appropriately to actuate the exhaust valve **100**. As shown in FIG. 3, a first port **104** is defined in the valve housing **102**. The first port **104** receives pressurized fluid directly from the distribution manifold **62**. See FIGS. 2A-2B. Thus, there is a constant source of pressurized fluid entering the first port **104**. A second port **106** is defined in the valve housing **102** adjacent to the first port **104**. The second port **106** is in operative communication with the pilot valve **200** such that the pilot valve **200** controls the flow of pressurized fluid into and out from the second port **106**. The selective introduction of pressurized fluid into and out from the second port **106** controls movement of a sliding sleeve **108**.

[0043] In an initial stage, illustrated in FIG. 4A, the sliding sleeve **108** covers a plurality of ports **110** defined and spaced annularly about the power barrel **52**. In this stage, the pilot valve **200** is in a ready or initial position, i.e., the trigger **38** has not been pulled. Thus, the first **104** and second **106** ports both receive pressurized fluid at generally the same pressure. However, since an area of a proximal annular surface **112** of the sliding sleeve **108** operative with the second port **106** is greater than an area of a distal annular surface **114** of the sliding sleeve **108** operative with first port **104**, the sliding sleeve **108** is biased in a closed position to cover the plurality of ports **110**. Arrows are used throughout the Figures to indicate fluid flow in each of the stages illustrated for each of the valves.

[0044] First **116** and second **118** fluid envelopes, in operative communication with the first **104** and second **106** ports, provide access to the annular surfaces **112, 114** of the sliding sleeve **108**. Seal rings **120** that are concentrically fixed to the power barrel **52** both proximally and distally of the plurality of ports **110** create this configuration. The sliding sleeve **108** slides across the seal rings **120** to cover and uncover

the plurality of ports **110**. The valve housing **102**, power barrel **52**, seal rings **120**, and sliding sleeve **108** are sized and configured so as to permit relatively free motion of the sliding sleeve **108** while maintaining integrity of the sealing method employed. The sliding sleeve **108** should be formed from lightweight material to minimize inertia. In addition, a flow capacity of a fluid circuit **121** between the second envelope **118** and the pilot valve **200** is equal to or slightly greater than a flow capacity of the pilot valve **200** to minimize flow time.

[0045] Referring briefly to FIG. 4D, in the initial stage, pressurized fluid is also introduced into the chamber **48** distally of the piston **54** to return or maintain the piston **54** in the un-actuated position. An air groove **122** in the sliding sleeve **108** permits the movement of the pressurized fluid from the first port **104** into the chamber **48** through the ports **110**.

[0046] In a second stage, illustrated in FIG. 4B, the trigger **38** has been pulled and pressurized fluid is released out from the second port **106**. As will be described further below, the second port **106** is exposed to atmospheric pressure via the pilot valve **200**. When this transition in fluid flow occurs, the fluid pressure provided by the second port **106** across the proximal annular surface **112** of the sliding sleeve **108** is removed and the sliding sleeve **108** slides proximally due to the continued pressure on the distal annular surface **114** provided by the first port **104**. In this stage, the piston **54** is latched to the proximal end **44** in the un-actuated position.

[0047] In the final stage, illustrated in FIG. 4C, the sliding sleeve **108** is fully retracted to uncover the plurality of ports **110** in the power barrel **52**. The ports **110** are exposed directly to the atmosphere and due to the pressure differential across the piston **54**, as previously described, the piston **54** travels ferociously toward the tool bit **24** from the proximal end **44** to impact the tool bit **24** and drive the tool bit **24** toward the workpiece **22**. When the trigger **38** is released, pressurized fluid is again directed into the second port **106** behind the proximal annular surface **112** to slide the sliding sleeve **108** back across the plurality of ports **110**, as illustrated in the initial stage of FIG. 4A. An air gap **115** remains behind the proximal annular surface **112** even when the sliding sleeve **108** is fully retracted. This ensures that the sliding sleeve **108** can be returned to an extended position to cover the ports **110** after actuation.

[0048] With reference to FIGS. 5A-5D, the pilot valve **200** is further described. The pilot valve **200** comprises a valve housing **202** defining a pilot chamber

204. The valve housing **202** may comprise two sealed portions, as shown, or may comprise a single unitary piece. A plunger **206** is slidably and concentrically supported within the pilot chamber **204** to actuate the pilot valve **200** and control the exhaust valve **100**. The trigger **38** slides the plunger **206** within the pilot chamber **204**. A first port **208** is in continuous fluid communication with the distribution manifold **62**. See FIGS. 2A-2B. Thus the first port **208** is in continuous communication with the pressurized fluid source **F**. A second port **210** is in direct fluid communication with the second port **106** of the exhaust valve **100**. A third port **212** exposes the pilot chamber **204** to the atmosphere.

[0049] The plunger **206** includes first **214**, second **218**, and third **228** annular seals to selectively seal and unseal portions of the pilot chamber **204** to control the exhaust valve **100**. A spring **216** is retained at an intermediate position on the plunger **206** and coaxially surrounds the plunger **206**. The spring **216** biases the first annular seal **214** against a shoulder **220** of the plunger **206**. Linear displacement of the plunger **206** progressively closes the first port **208** and compresses the spring **216** to snap the first annular seal **214** off of a poppet seat **222** to abruptly open fluid communication between the second **210** and third **212** ports. The valve has a very sudden one-way transition characteristic once the actuation cycle passes a threshold, similar to the action of a toggled light switch.

[0050] In an initial stage, referring to FIG. 5A, the plunger **206** is at an initial, un-actuated position. In this position the first annular seal **214** is sealed against the poppet seat **222** and pressurized fluid from the distribution manifold **62** is routed through the first port **208** into the second port **210** and to the exhaust valve **100**. As previously described, in this stage, the pressurized fluid is introduced into the chamber **48** distally of the piston **54** to latch the piston **54** to the proximal end **44** of the casing **42**. A narrow angled passage **224** provides pressurized fluid behind a chamfered end **226** of the plunger **206** to bias the plunger **206** toward the trigger **38**. Furthermore, in the initial stage, the third port **212** is closed to fluid communication with the first **208** and second **210** ports via the first annular seal **214**.

[0051] In a second and third stage, illustrated in FIGS. 5B and 5C, respectively, the plunger **206** is depressed by the trigger **38** and the second annular seal **218** closes fluid communication between the first **208** and second **210** ports. In these stages, the spring **216** begins to compress and a biasing force of the spring **216** continues to urge the first annular seal **214** away from the poppet seat **222**.

[0052] In a final, actuated stage, illustrated in FIG. 5D, the plunger **206** is fully depressed in the pilot chamber **204** and under the biasing force of the spring **216**, the first annular seal **214** unseats from the poppet seat **222** and slides back to the shoulder **220**. This action opens fluid communication between the second **210** and third **212** ports thus releasing the pressurized fluid from the second port **106** of the exhaust valve **100** to the atmosphere, as previously described, causing the sliding sleeve **108** to open the ports **110** in the power barrel **52** resulting in a sudden thrust of the piston **54** against the tool bit **24**.

[0053] With reference to FIGS. 6A-6C and 7-8, the bleeder valve **300** is further described. The bleeder valve **300** includes a valve housing **302** sealed to the proximal end **44** of the power barrel **52**. Thus the valve housing **302** acts as an end cap of the power barrel **52**. The valve housing **302** defines an annular envelope **304** concentric with the power barrel **52**. A variable capacity fluid passage **306** extends between the annular envelope **304** and the atmosphere. A timing screw **308** is adjustably positioned in the valve housing **302** to vary the capacity of the variable capacity fluid passage **306**. Adjusting the timing screw **308** controls the timing of the bleeder valve **300**. The valve housing **302** also defines a first port **310** in fluid communication with the chamber **48** when the piston **54** moves distally from the valve housing **302** within the chamber **48** upon actuation.

[0054] A poppet body **312** provides fluid communication between the first port **310** and the annular envelope **304** to bleed pressurized fluid from the chamber **48** to the atmosphere. The timing screw **308** adjusts this bleed rate to adjust a cracking rate of the poppet body **312** as further described below. The poppet body **312** is slidably and concentrically sealed within a rear cavity **314** of the valve housing **302**. The poppet body **312** is lightweight and includes first **316** and second **318** grooves (see FIG. 8) for first **320** and second **322** seals. The poppet body **312** defines first **324** and second **326** narrow passages and a plurality of ports **328** for fluid flow. The poppet body **312** is preferably formed from a low-friction, non-corroding material, e.g., acetal, to minimize inertial and frictional latency. A spring plug **330** is retained via a retainer clip **332** within the rear cavity **314** of the valve housing **302** proximally to the poppet body **312**. A spring **334** is seated in the spring plug **330** to bias the poppet body **312** into the first port **310** of the valve housing **302**. A spring screw **336** adjusts the biasing force of the spring **334** on the poppet body **312** to adjust a cracking pressure of the poppet body **312**.

[0055] In an initial stage, illustrated in FIG. 6A, the bleeder valve **300** remains closed while the piston **54** remains seated against a seat **338** and seal **340** of the valve housing **302**, thus sealing pressurized fluid from the bleeder valve **300**. The bleeder valve **300** also remains closed during a delay period after the piston **54** accelerates forward upon actuation. In this stage, the chamber **48** is fully pressurized, i.e., the exhaust valve **100** is closed. A space **341** provides fluid access from the reserve chamber **58** proximally of the piston **54**. A port is defined in the power barrel **52** to feed pressurized fluid from the reserve chamber **58** to the space **341**. The reserve chamber **58** continuously provides pressurized fluid proximally of the piston **54** at a pressure less than the pressurized fluid source **F**, as previously described.

[0056] In a second stage, illustrated in FIG. 6B, the tool **20** has been actuated and the piston **54** has slid distally within the chamber **48**. This exposes the bleeder valve **300** to the pressurized fluid provided by the reserve chamber **58** behind or proximally to the piston **54**. Exposure of the bleeder valve **300** to pressurized fluid begins a timing sequence to crack the poppet body **312** after a predetermined delay, as controlled by the timing screw **308**. Prior to the poppet body **312** cracking, the poppet body **312** begins to compress the spring **334** and displace the seals **320** and **322**. This occurs as pressure builds on the poppet body **312** from the first port **310** and the annular envelope **304**. Ultimately, the poppet body **312** yields to the pressure from the annular envelope **304** to crack the poppet body **312**. The rate of pressure build-up in the annular envelope **304** is controlled by the timing screw **308** and the associated rate of release of pressurized fluid to the atmosphere via the variable capacity fluid passage **306**. Upon cracking, the poppet body **312** accelerates quickly to create a pressure drop to enable the piston return cycle. FIG. 6B illustrates the poppet body **312** immediately before cracking.

[0057] In a final stage, illustrated in FIG. 6C, the bleeder valve **300** is fully opened to more rapidly expel the pressurized fluid provided by the reserve chamber **58** to the atmosphere to enable the piston return cycle. In this stage, pressurized fluid in the chamber **48** passes to the atmosphere through the spring plug **330**. Here, a nose **342** (see FIG. 8) of the poppet body **312** is withdrawn from the first port **310**, exposing an entire cross-section of the poppet body **312** to the pressurized fluid, which thrusts the second seal **322** of the poppet body **312** beyond a seat thereof, opening flow passages between the seat and an air groove **346** of the poppet body **312**. This is the cracking of the poppet body **312** as described above. The open flow position of the poppet body **312** is controlled by a

balance between a flow-induced pressure drop and a setting of the spring **334**. The variable control of the bleeder valve **300** allows the piston **54** to return back to the seat **338** at a desired rate.

[0058] With reference to FIGS. 9A-9C, 10A-10C, and 11-12, the energy absorbing mechanism **402** is described. Kinetic energy is transferred from the piston **54** upon actuation to the tool bit **24** by one or more elastic collisions. This kinetic energy is dissipated by collision of the tool bit **24** with the workpiece **22** (not shown in FIGS. 9A-9C and 10A-10C) and/or by a secondary series of elastic collisions along with a multi-stage compression and release of pressurized fluid through the restrictor orifice **400**. The energy absorbing mechanism **402** ensures that in the event the tool bit **24** misses the workpiece **22**, e.g., during a dry fire, the kinetic energy is safely dissipated.

[0059] The energy absorbing mechanism **402** comprises a sleeve **404** concentrically and sealably supported by the tool barrel **50**. The sleeve **404** is slidable along the tool barrel **50**. In particular, the sleeve **404** has a proximal end **401** including an annular sealing ring **403** fixed thereto for slidably sealing the sleeve **404** to an outer surface of the tool barrel **50**. The sleeve **404** also includes a distal end **405** having a main body **407** defining an orifice for receiving the tool bit **24**. A first annular wall **406** extends coaxially and proximally from the main body **407** into the tool barrel **50**. A second annular wall **408** is coaxially spaced from the first annular wall **406** and extends coaxially and proximally from the main body **407** about the outer surface of the tool barrel **50**. An annular groove is defined between the annular walls **406**, **408** and the tool barrel **50** slides within the annular groove as the sleeve **404** slides along the tool barrel **50**.

[0060] A first pressure chamber **412** is defined between the tool bit **24**, the tool barrel **50**, and the first annular wall **406** of the sleeve **404**. Pressurized fluid in the first pressure chamber **412** begins to reduce the kinetic energy of the tool bit **24** immediately after impact by the piston **54**. A second pressure chamber **414** is defined between the outer surface of the tool barrel **50**, a flange **411** of the tool barrel, the annular sealing ring **403**, and the second annular wall **408** of the sleeve **404**. Thus, the first **412** and second **414** pressure chambers are radially offset from one another relative to the operational axis **A**. Pressurized fluid in the second pressure chamber **414** reduces the kinetic energy of the tool bit **24** immediately after impact of the sleeve **404** by the tool bit **24**. Thus, the dissipation of the kinetic energy occurs in multiple stages. One of which includes the compression of fluid within the first pressure chamber **412**, while another includes the compression of fluid

within the second pressure chamber **414**.

[0061] The power barrel **52** defines a fluid passage **416** for providing fluid communication between the first **412** and second **414** pressure chambers. A first end of the fluid passage **416** further includes the restrictor orifice **400** to restrict fluid flow into and out from the fluid passage **416**. Referring to FIGS. 9A-9C, the restrictor orifice **400** is in direct fluid communication with the chamber **48** distally of the piston **54**, such that as the chamber **48** is filled with pressurized fluid in the piston return cycle, the fluid passage **416** also pressurizes the pressure chambers **412, 414**. Thus, the chamber **48** is a source of pressurized fluid that is connected to the first end of the fluid passage **416** to pressurize the first **412** and second **414** pressure chambers. Similarly, as the pressurized fluid is exhausted from the chamber **48** distally of the piston **54** upon actuation, pressurized fluid from the pressure chambers **412, 414** is slowly bled via the restrictor orifice **400**.

[0062] The tool bit **24** and the piston **54** are independent and separable components and the piston **54** slides within the chamber **48** upon actuation of the exhaust valve **100** to impact the tool bit **24** and drive the tool bit **24** into the workpiece **22**. The tool barrel **50** and the sleeve **404** define a bleed passage **418** (see FIG. 10D) therebetween whereby the tool bit **24** compresses the fluid out from the first pressure chamber **412** through the bleed passage **418** and fluid passage **416** and into the second pressure chamber **414** after the tool bit **24** begins to travel distally upon impact by the piston **54**.

[0063] Preferably, the tool bit **24** comprises a bit **420** having a head **422** and a ram **426** for impacting the head **422** of the bit **420**. The tool barrel **50** includes proximal and distal ends and the tool barrel **50** defines a bore in the proximal end for slidably and concentrically receiving and supporting the ram **426**. An impact chamber is defined between the proximal end of the tool barrel **50** and the head **422**. The ram **426** impacts the head **422** of the bit **420** within the impact chamber. The fluid in the first pressure chamber **412** is compressed and bleeds into the second pressure chamber **414** as the head **422** of the bit **420** slides distally within the impact chamber.

[0064] A vent port **436** is defined within the tool barrel **50** to prevent a vacuum in the impact chamber when the bit **420** is driven distally by the ram **426**. A vent port **438** is defined within the sleeve **404** to prevent a vacuum between the sleeve **404** and the tool barrel **50** as the sleeve **404** sealably slides along the tool barrel **50** to reduce the kinetic energy of the tool bit **24**.

[0065] In FIGS. 9A-9C and 10A-10C, the proximal end **44** of the casing **42**, which normally includes the bleeder valve **300** previously described, instead illustrates a conventional end cap. This is for illustrative purposes only. This end cap is shown as defining an orifice for receiving the pressurized fluid from the reserve chamber **58**. See FIGS. 2A-2B. Thus, the fluid circuits illustrated in FIGS. 9A-9C and 10A-10C are generically illustrated to show the operation of the energy absorbing mechanism **402**. In actual operation, the bleeder valve **300** would be positioned in the power barrel **52** at the proximal end **44** and a port would provide fluid communication with the reserve chamber **58**, as shown in FIGS. 6A-6C.

[0066] In an initial stage, illustrated in FIGS. 9A and 10A, the fluid passage **416** and the pressure chambers **412**, **414** are provided with pressurized fluid from the chamber **48** distally of the piston **54** via the distribution manifold **62** as controlled by the exhaust valve **100** and the pilot valve **200**, while the fluid proximal to the piston **54**, is provided by the reserve chamber **58** at a pressure less than the pressure of the fluid distal to the piston **54**. Hence, the piston **54** is latched to the proximal end **44** of the casing **42** and the tool bit **24** is in the starting position.

[0067] In a second stage, illustrated in FIGS. 9B and 10B, the pressurized fluid in the chamber **48** distal to the piston **54** has been released to the atmosphere. The piston **54** has impacted the tool bit **24** sending the bit **420** toward the sleeve **404** thus compressing the fluid in the first pressure chamber **412**. As the fluid in the first pressure chamber **412** is further compressed, the fluid bleeds into the second pressure chamber **414** via the bleed passage **418** and the fluid passage **416**. Pressurized fluid is also slowly released to the atmosphere via the restrictor orifice **400**. In this stage, the process of fluid compression and release dissipates some of the bit's kinetic energy, roughly inversely proportional to a volume contraction of the first pressure chamber **412**.

[0068] In a final stage, illustrated in FIGS. 9C and 10C, the bit **420** has impacted the sleeve **404** and fully compressed the first pressure chamber **412**. The sleeve **404** slides along the tool barrel **50** and compresses the second pressure chamber **414**. At the same time, additional pressurized fluid is released from the second pressure chamber **414**, through the fluid passage **416** and the restrictor orifice **400**. Hence, with the slow bleed of pressurized fluid from the restrictor orifice **400**, the first **412** and second **414** pressure chambers partially absorb the kinetic energy imparted to the bit **420** by the piston **54** and ram **426**, while at the same time bleeding the kinetic energy via the restrictor orifice **400**. In

this stage, the process of fluid compression and release dissipates more of the bit's kinetic energy, roughly inversely proportional to a volume contraction of the second pressure chamber **414**.

[0069] The piston **54**, sleeve **404**, ram **426**, and bit **420** are very high strength, hardened, alloy steels, capable of interacting in a chain of energetic, almost perfectly elastic collisions. They are sized and configured, in conformance with conservation of linear momentum and fluid dynamics principles, to yield a desired balance between transfer and dissipation of kinetic energy. The collision chain shown here is not meant as a limiting configuration.

[0070] The fluid passage **416** and restrictor orifice **400** are sized and configured to produce desired rates of deceleration and energy dissipation. In alternative embodiments, the restrictor orifice **400** may be closed to outflow by a checkvalve (not shown).

[0071] With reference to FIGS. 13A-13C and 14, the shock absorbing valve **500** is further described. A floating collar **502** is slidably and concentrically coupled to the power barrel **52** between two seal rings **504** fixably and sealably concentric about the power barrel **52** so as to oppose each other. First **506** and second **508** annular envelopes are defined between the floating collar **502**, the seal rings **504**, and the power barrel **52**. The floating collar **502** is cylindrical with a first section **510** sealably and slidably concentric around the power barrel **52** with an abutting, larger diameter section **512** at either end sealably and slidably concentric around the seal rings **504**. The handle **34** is mounted to the floating collar **502**, as described further below.

[0072] A manifold passage **514** is defined in the floating collar **502**. A first port **516** is bored in the floating collar **502** to access the manifold passage **514**. A restrictor passage **518** having a pressure regulator **520** therein regulates the flow of pressurized fluid into the manifold passage **514** from the distribution manifold **62** in accordance with well-known principles of pressure regulation. The pressure regulator **520** is adjustable to tune the tool **20** to correspond to multiple pressure rates from the pressurized fluid source **F**. Referring specifically to FIG. 14, the pressure regulator **520** is a cylindrical, lightweight, and corrosion-free body formed preferably from acetal, that is sealably and slidably concentric in the restrictor passage **518**. The pressure regulator **520** has grooves for seals **524** and a bleed passage **526** for regulating the pressure in the shock absorbing valve **500**.

[0073] Referring back to FIG. 13A, a pair of angled fluid passages **528** provides fluid communication between the manifold passage **514** and the annular envelopes **506**, **508**. A first **530** and second **532** pair of exhaust ports release pressurized fluid from the first **506** and second **508** envelopes to the atmosphere, respectively, upon actuation of the shock absorbing valve **500**.

[0074] In an initial stage, illustrated in FIG. 13A, the floating collar **502** rests in equilibrium, with the first **506** and second **508** envelopes being at equilibrium with one another until a force, e.g., recoil from acceleration of the piston **54** in the chamber **48**, displaces the floating collar **502**, compressing one of the envelopes **506**, **508** and expanding the other, raising the pressure in the former and lowering the pressure in the latter.

[0075] In a second stage, illustrated in FIG. 13B, displacement of the floating collar **502** vents the second envelope **508** to the atmosphere via the second pair **532** of exhaust ports. In this stage, the floating collar **502** is shown being displaced distally relative to the seal rings **504**. This lowers the pressure in the second envelope **508** while increasing the pressure in the first envelope **506**.

[0076] In a final stage, illustrated in FIG. 13C, the floating collar **502**, under the pressure in the first envelope **506** slides back proximally relative to the power barrel **52**. Thus, the pressure changes in the first **506** and second **508** envelopes via the pressurizing fluid supplied by the manifold passage **514** and the release of the pressurized fluid via the exhaust ports **530**, **532**, absorbs recoil of the tool **20** during use by striving to reach an equilibrium pressure condition within the envelopes **506**, **508**.

[0077] With reference to FIGS. 15 and 16, the pressure reducing check valve **600** is further described. The pressure reducing check valve **600** is a tight-sealing, pressure-reducing check valve. The check valve **600** is designed to provide quick response and high-flow capacity to be easily integrated into the tool **20**. The check valve **600** can be adjusted to provide a pressure reduction of a few pounds per square inch up to twenty pounds per square inch or more. The check valve **600** is used to isolate the reserve chamber **58** to facilitate high-efficiency design. The check valve **600** comprises a valve housing **602**, a poppet body **604**, a poppet seal **606**, a spring **608**, a retainer **610**, and a seat washer **612**.

[0078] The valve housing **602** is solid with a cylindrical cavity having an inlet **614** and outlet **616** passage and grooves to retain the poppet seal **606** and retainer **610**. Referring briefly to FIG. 16, the poppet body **604** is a cylindrical lightweight solid with a rounded conical nose **620**, a number of concave front-to-back, parallel-to-axis, airflow

grooves **622**, and a spring cavity **624** defining a back end. The poppet seal **606** is an elastic solid to provide a seat for the poppet body **604** to seal against and restrict flow at a desired pressure drop. The seat washer **612** and retainer **610** provide for retention of the poppet seal **606**. The spring **608** is a compression spring configured to provide proper force and travel for desired valve cracking and opening characteristics. A spring shim washer adjusts spring compression to the desired cracking pressure differential (pressure reduction).

[0079] In operation, the spring **608** and pressurized fluid downstream of the check valve **600** seals the poppet body **604** to close flow until the downstream pressure drops below the cracking pressure. Upstream pressure then forces the poppet body **604** away from the poppet seal **606** and flow proceeds via the airflow grooves **622** as downstream conditions dictate. Using a lightweight solid to minimize latency, the poppet body **604** can be configured with a nose angle, length to diameter ratio, groove cross-sectional area and spring rate/travel so as to provide very responsive cracking and high-flow characteristics in a very compact size.

[0080] Referring to FIG. 17, a mounting arm **63** mounts the handle **34** to the floating collar **502** and a mounting bracket **65** mounts the cuff **32** to the floating collar **502**. The mounting arm **63** is rectangular and solid with appropriate passages and attachments or fasteners to position the handle **34** in alignment with the cuff **32** and trigger **38**. The mounting arm **63** bridges the handle **34** and the floating collar **502**.

[0081] The handle **34** comprises a grip sleeve **64** that is rectangular and made from elastomeric, pliable material, having exterior contours ergonomically conformable to the hand of the operator. A grip core tube **66** tightly slip fits into the grip sleeve **64**. A floating grip core retainer **68** slides into an underside of the grip sleeve **64**. The floating grip core retainer **68** is rectangular and includes a flange **70** at a bottom end with a fluid passage **72** therethrough. A spring-loaded fastener **74** is sized to fit slidably into the grip core tube **66** and the grip sleeve **64** so as to retain them on the valve housing **202** of the pilot valve **200** in a manner forgiving to flexing or accidental impact.

[0082] An alternative handle **76** is shown in FIG. 18. The alternative handle **76** comprises a post **78** formed from metal that is fixed to either the valve housing **202** of the pilot valve **200** or other position on the mounting arm **63**. A transparent elastomeric material is formed about the post **78** to form a grip **80**. Indicia **82** is embossed, e.g., raised, on the post **78** such that the indicia **82** is visible to the operator through the grip **80** to create an aesthetically pleasing visual representation of the indicia. The indicia **82**

may be integrally formed in the post **78** or may be a separate component fixed to the post **78**. In alternative embodiments, the indicia **82** is not raised, but is merely printed on the post **78**, or comprises a sticker affixed to the post **78**. The post **78** is generally rectangular in shape and includes a hollow cavity **84** for mounting the handle **76** to the tool **20**. The post **78** also defines a plurality of grooves **86** for further securing the grip **80** to the post **78**. The handle **76** includes a first bore **88** extending longitudinally therethrough at a generally central position to mount the handle **76** to the tool **20** via a fastener (not shown). The handle **76** also includes a second bore **90** extending longitudinally therethrough adjacent to the first bore **88**. The second bore **90** provides an exhaust passage for exhausting pressurized fluid from the third port **212** of the pilot valve **200** to the atmosphere.

[0083] The tool **20** is an integration of innovative features and components, including valving, kinetic energy generation/transfer and ergonomics. The tool **20** comprises a series of concentric cylindrical envelopes and cylinders, with integrated or attached fluid flow control circuitry and components, operating in a very efficient single-stroke mode, developing high power in a very compact, lightweight and maneuverable form. The tool **20** produces high-energy, high-acceleration impacts and delivers them with a long-excursion transfer/tool bit assembly capable of dry firing without damaging tool components. The tool **20** embodies an operator interface innovation that features a dynamic fluid-flow recoil damping system coupled to a forgiving cuff/handle configuration that makes the tool **20** a virtual extension of the operator's arm and hand, enabling very comfortable, low-shock, and nimble, one hand operation.

[0084] Obviously, many modifications and variations of the present invention are possible in light of the above teachings. The invention may be practiced otherwise than as specifically described within the scope of the appended claims, wherein that which is prior art is antecedent to the novelty set forth in the "characterized by" clause. The novelty is meant to be particularly and distinctly recited in the "characterized by" clause whereas the antecedent recitations merely set forth the old and well-known combination in which the invention resides. These antecedent recitations should be interpreted to cover any combination in which the incentive novelty exercises its utility. In addition, the reference numerals in the claims are merely for convenience and are not to be read in any way as limiting.